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EVALUATION OF CANDIDATE SOLVENT BASED PAINT STRIPPERS FOR THE REPLACEMENT OF METHYLENE CHLORIDE BASED PAINT STRIPPERS – PHASE II

R.D. Haggett – J.A. Hiltz

DEFENCE RESEARCH ESTABLISHMENT ATLANTIC

Technical Memorandum

DREA TM 2000-053

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DREA TM 2000-053

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May 2000

TECHNICAL MEMORANDUM

Prepared by

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Centre de Recherches pour la Défense Atlantique

DEFENSIO PER SCIENTIAM

Canada

ABSTRACT

The stripping effectiveness of Fine Organics FO606 and Turco 5668 have been evaluated and compared to Oakite Stripper SA. Testing was carried out in the Chemical Cleaning Facility, FMF Cape Scott on pipe sections and elbows coated with a white powder epoxy coating as well as pipe brackets and valve covers coated with a black spray epoxy coating. All paint strippers were used in accordance with the manufacturers recommended procedures.

The results indicate that Fine Organics FO606 removed 100% of the white powder epoxy coating after 4 hours and 90% of the black spray epoxy coating after 6 hours. This result was similar to the methylene chloride based stripper that removed 100% of the white powder epoxy after 2 hours and 100 % of the black spray epoxy after 6 hours. However, Turco 5668 removed 95% of the white powder epoxy after 6 hours but less than 5% of the black spray epoxy after 24 hours.

Monitoring of Volatile Organic Compounds (VOCs) indicated that there were no serious health concerns with the use of N-methylpyrrolidone (NMP)/ethanolamine based solvents in properly ventilated cleaning facilities.

A cost analysis indicated that Fine Organics FO606 was almost twice as expensive as Oakite Stripper SA (~$12.50 CND/L versus ~$7.00 CND/L). The cost of Turco 5668, which was ineffective as a stripper for the black spray epoxy coating, was $13.30 CND/L.

RÉSUMÉ

Nous avons évalué l'efficacité de deux décapants, soit Fine Organics FO606 et Turco 5668, et les avons comparés au produit de marque Oakite Stripper SA. Nous avons effectué les essais à l'installation de nettoyage chimique de l'IMF Cape Scott, sur des sections de tuyaux et des coudes enduits d'un revêtement époxy blanc en poudre et sur des supports de tuyaux et des cache-soupapes enduits d'un revêtement époxy noir pulvérisé. Tous les décapants ont été utilisés conformément aux instructions des fabricants.

Les résultats indiquent que le décapant Fine Organics FO606 enlève 100 % du revêtement époxy blanc en poudre après une période de quatre heures et 90 % du revêtement époxy noir pulvérisé après une période de six heures. Ces résultats sont semblables à ceux obtenus avec le décapant à base de chlorure de méthylène qui enlève 100 % du revêtement époxy blanc en poudre après une période de deux heures et 100 % du revêtement époxy noir pulvérisé après une période de six heures. Le décapant Turco 5668, toutefois, enlève 95 % du revêtement époxy blanc en poudre après une période de six heures mais moins de 5 % du revêtement époxy noir pulvérisé après une période de 24 heures.

Les mesures relatives à la surveillance des émissions de COV (composés organiques volatils) indiquent que l'utilisation de solvants à base de N-méthylpyrrolidone (NMP) et d'éthanolamine, dans des installations de nettoyage convenablement aérées, ne représente pas un danger grave pour la santé.

L'analyse des coûts révèle que le décapant Fine Organics FO606 est presque deux fois plus coûteux que le produit Oakite Stripper SA (℘ 12,50 $CAN/L par rapport à ℘ 7,00 $CAN/L). Le coût du produit Turco 5668, qui est un décapant inefficace pour le revêtement époxy noir vaporisé, est de 13,30 $CAN/L.

DREA TM 2000-053

Evaluation of Candidate Solvent Based Paint Strippers for the Replacement of Methylene Chloride Based Paint Strippers – Phase II

by

Randall D. Haggett and John A. Hiltz

Executive Summary

Introduction

Alternatives to methylene chloride paint strippers are required because of concerns about the carcinogenicity of methylene chloride. In Phase I of this project the effectiveness of seven methylene chloride free paint strippers were evaluated to determine if they were suitable alternatives to a methylene chloride based stripper presently in use (Oakite Stripper SA). In addition to paint stripping effectiveness, health and environmental hazards associated with the handling use and disposal of the replacement strippers were evaluated. Two candidate strippers were identified for further testing; Fine Organics FO606 and Turco 5668. Both products contained N-methylpyrrolidone (NMP) and ethanolamine as the major active ingredients.

In phase II of this project the stripping effectiveness of Fine Organics FO606 and Turco 5668 were compared to Oakite Stripper SA. Testing was carried out in the Chemical Cleaning Facility, FMF Cape Scott on pipe sections and elbows coated with a white powder epoxy coating as well as pipe brackets and valve covers coated with a black spray epoxy coating. All paint strippers were used in accordance with the manufacturers recommended procedures.

Principal Results

The results indicate that Fine Organics FO606 removed 100% of the white powder epoxy coating after 4 hours and 90% of the black spray epoxy coating after 6 hours. This result was similar to the methylene chloride based stripper that removed 100% of the white powder epoxy after 2 hours and 100 % of the black spray epoxy after 6 hours. However, Turco 5668 removed 95% of the white powder epoxy after 6 hours but less than 5% of the black spray epoxy after 24 hours.

Monitoring of Volatile Organic Compounds (VOCs) indicated that there were no serious health concerns with the use of N-methylpyrrolidone (NMP)/ethanolamine based solvents in properly ventilated cleaning facilities

A cost analysis indicated that Fine Organics FO606 was almost twice as expensive as Oakite Stripper SA (~$12.50 CND/L versus ~$7.00 CND/L). The cost of Turco 5668, which was ineffective as a stripper for the black spray epoxy coating, was $13.30 CND/L.

Significance of Results

The work carried out during both Phase I and Phase II of this project clearly demonstrated that industry is making a serious effort to the replace potentially hazardous and environmentally unfriendly chemicals used for paint stripping with more benign products. However, a chemical or chemical mixture that is as effective and as inexpensive as methylene chloride has yet to be identified. This project has shown that N-methylpyrrolidone, when used at a concentration greater than 60 percent in an alkaline solution is a suitable substitute for methylene chloride as a paint stripper. Unfortunately the cost associated with the routine use of n-methylpyrrolidone based paint strippers may be prohibitive.

This work was funded under a tasking from DGE/DEnvP 2-2.

CRDA TM 2000-053

Évaluation de décapants à peinture à base de solvant d'intérêt pouvant remplacer les décapants à base de chlorure de méthylène – Phase II
par
Randall D. Haggett et John A. Hiltz

Sommaire

Introduction

Les inquiétudes relatives à la cancérogénicité du chlorure de méthylène exigent que l'on trouve des produits de remplacement pour les décapants à peinture à base de chlorure de méthylène. Dans la phase I du présent projet, nous avons évalué l'efficacité de sept décapants à peinture ne contenant pas de chlorure de méthylène afin de déterminer s'ils étaient des produits de remplacement appropriés pour un décapant à base de chlorure de méthylène présentement utilisé (le produit Oakite Stripper SA). En plus de l'efficacité des décapants, nous avons aussi évalué les dangers pour la santé et pour l'environnement associés à la manutention, l'utilisation et l'élimination de ces produits de remplacement. Deux décapants d'intérêt ont été sélectionnés pour des essais plus poussés, soit les produits Fine Organics FO606 et Turco 5668. Les deux produits contiennent de la N-méthylpyrrolidone (NMP) et de l'éthanolamine comme ingrédients actifs principaux.

Dans la phase II du présent projet, nous avons évalué l'efficacité des deux décapants, Fine Organics FO606 et Turco 5668, et les avons comparés au produit de marque Oakite Stripper SA. Nous avons effectué les essais à l'installation de nettoyage chimique de l'IMF Cape Scott, sur des sections de tuyaux et des coudes enduits d'un revêtement époxy blanc en poudre et sur des supports de tuyaux et des cache-soupapes enduits d'un revêtement époxy noir pulvérisé. Tous les décapants ont été utilisés conformément aux instructions des fabricants.

Résultats principaux

Les résultats indiquent que le décapant Fine Organics FO606 enlève 100 % du revêtement époxy blanc en poudre après une période de quatre heures et 90 % du revêtement époxy noir pulvérisé après une période de six heures. Ces résultats sont semblables à ceux obtenus avec le décapant à base de chlorure de méthylène qui enlève 100 % du revêtement époxy blanc en poudre après une période de deux heures et 100 % du revêtement époxy noir pulvérisé après une période de six heures. Le décapant Turco 5668, toutefois, enlève 95 % du revêtement époxy blanc en poudre après une période de six heures mais moins de 5 % du revêtement époxy noir pulvérisé après une période de 24 heures.

Les mesures relatives à la surveillance des émissions de COV (composés organiques volatils) indiquent que l'utilisation de solvants à base de N-méthylpyrrolidone (NMP) et d'éthanolamine, dans des installations de nettoyage convenablement aérées, ne représente pas un danger grave pour la santé.

L'analyse des coûts révèle que le décapant Fine Organics FO606 est presque deux fois plus coûteux que le produit Oakite Stripper SA (℘ 12,50 $CAN/L par rapport à ℘ 7,00 $CAN/L). Le coût du produit Turco 5668, qui est un décapant inefficace pour le revêtement époxy noir vaporisé, est de 13,30 $CAN/L.

Interprétation des résultats

Les travaux effectués au cours des phases I et II du présent projet démontrent clairement que l'industrie fait de grands efforts pour remplacer les produits chimiques utilisés comme décapants à peinture et potentiellement dangereux pour la santé et l'environnement par des produits moins nuisibles. Cependant, il n'a pas encore été possible d'identifier un produit chimique ou un mélange de produits chimiques qui est aussi efficace et aussi peu coûteux que le chlorure de méthylène. Les résultats du présent projet démontrent que la N-méthylpyrrolidone, en solution alcaline et à une concentration supérieure à 60 %, est un décapant à peinture de remplacement approprié du chlorure de méthylène. Les coûts associés à l'utilisation courante de décapants à peinture à base de N-méthylpyrrolidone pourraient malheureusement être exorbitants.

Les présents travaux ont été financés en vertu d'une attribution des tâches du DGE/DP Env 2-2.

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Introduction

The Department of National Defence (DND), Director General Environment (DGE), is committed to reduce the use of and exposure to any toxic chemical as much as possible. A DND initiative, the "Environmentally Sustainable Defence Activities", is actively involved with reducing the use of specified "high-risk hazardous materials" by 5% per year and significantly reducing the quantities of hazardous waste sent for disposal [1]. Health Canada has determined that methylene chloride is "toxic" to human health and long term exposure to high levels has been associated with an increased incidence of cancer in laboratory animals [2]. As a result of the health concerns associated with the use of products containing methylene chloride a project was initiated to evaluate alternatives to methylene chloride based paint strippers used in the Chemical Cleaning Facility, FMF Cape Scott.

During Phase I of this project the effectiveness of seven methylene chloride free paint strippers (Fine Organics FO 606, Brulin Safety Strip, Turco 5668, Patclin 103B and 104C, Dupont DBE-3, Santosol DME-1) was assessed [3]. The purpose of this evaluation was to determine if a suitable alternative to the methylene chloride based paint stripper (Oakite Stripper SA), presently used by DND could be found. This assessment included an evaluation of the ability of the candidate strippers to strip paint as well as the health and environmental hazards associated with their use.

Based on the results of this study, three solvents (Fine Organics FO 606, Brulin Safety Strip and Turco 5668) were identified as the 'best' available candidates to replace methylene chloride based stripping chemicals. The Material Safety Data Sheets stated that N-methylpyrrolidone (NMP) was present as the main component.

As a result of the Phase I evaluation, DREA/DL (A) was tasked, by DGE/DEnvP 2-2, to carry out an on-site evaluation of the most promising candidate solvents. The performance of the three paint strippers containing NMP was very similar (greater than 96% effective in removing spray epoxy, powder epoxy and polyurethane coatings), therefore, only two, FO 606 and the Turco 5668 were chosen for Phase II testing.

FO 606 was chosen because it was the most effective of the candidate strippers. Turco 5668, which ranked third, was chosen because it was available from a Canadian supplier.

In this memorandum, the paint stripping effectiveness of Fine Organics FO 606 and Turco 5668 are reported and compared to the effectiveness of the methylene chloride based stripper (Oakite Stripper SA) currently used. The stripping effectiveness was evaluated for a powder [commercially procured product] and a spray [4] epoxy coating. The testing was carried out in the Chemical Cleaning Shop, FMF Cape Scott.

Chemical Components of Candidate Paint Strippers

The two paint strippers selected for Phase II of this study were FO 606 (Fine Organics Corp., Lodi, New Jersey), and Turco 5668 (Dean & Company, Pointe Claire, Quebec). The components of these two products are listed in Table 1. Both Fine Organics FO 606 and Turco 5668 have a pH of 11-12.

Table 1. – Components of Fine Organics FO 606 and Turco 5668 Paint Strippers used in Phase II.

Product Name	Component	Percent
Fine Organics FO 606	1. Ethanolamine 2. N-Methylpyrrolidone	> 15 >60
Turco 5668	1. Potassium Hydroxide 2. Monoethanolamine 3. N-Methylpyrrolidone	1-5 30-60 10-30

It should be noted that the compositions of the Turco 5668 strippers used in Phase I and Phase II of this study were different. The Material Safety Data Sheets (MSDS) for Turco 5668 supplied for Phase I stated that the stripper contained between 40-60 % NMP. In contrast to this, the MSDS supplied with the Turco 5668 for Phase II stated that the product contained between 10-30 % NMP. The MSDS which accompanied the Turco

5668 supplied for both Phase I and Phase II of this project, as well as the MSDS for Fine Organics FO 606 and Oakite Stripper SA are included as Appendix A for comparison.

Test Procedure

Immersion Tests

Stripping effectiveness of the chemicals was evaluated at the Chemical Cleaning Shop, FMF Cape Scott. Testing was carried out in a 300-gallon heated solvent dip tank that was divided into 3-100 gallon sections. This allowed simultaneous testing of the two candidate stripping chemicals and the methylene chloride based stripper (Oakite Stripper SA).

All paint strippers were used in accordance with the manufacturers recommended procedures. The NMP based products were maintained at a temperature between 71°C and 82°C. Oakite Stripper SA did not require heating.

Test pieces for chemical paint stripping studies were supplied by the Chemical Cleaning Facility, FMF Cape Scott. They consisted of 50 centimeter (cm) lengths of 25 millimeter (mm) diameter copper nickel pipe and cast elbows (10 cm diameter) coated with white powder epoxy paint and metal pipe brackets and hull valve covers coated with black spray epoxy paint. All test pieces were from in-service systems and the paint was well cured.

The test pieces were immersed in the paint strippers and pieces were removed, rinsed with a high pressure water jet, and photographed after 2, 4, 6, 8 and 24 hours of immersion. No attempt was made to physically remove the paint from the test pieces. All test pieces were evaluated visually and the amount of paint removed was estimated as a percent of the total surface area.

Monitoring for Volatile Organic Compounds (VOC)

The VOC monitoring process was carried out over a two-day period. On day one (24 September 1999) shop personnel wore passive dosimeters as they carried out their normal duties. The shop used only Oakite Stripper SA on this day. The results obtained from the analysis of these dosimeters were used as background values.

On day two (1 October 1999) the shop personnel were given new dosimeters to wear in order to determine if measurable levels of VOC's were released from Fine Organics FO 606 and Turco 5668. To simplify interpretation of the VOC results each stripper tank was tended by a different shop employee. This was done in an attempt to determine if there was a difference in the concentration or composition of any VOCs that might be released from the two candidate strippers during the test period.

Analysis for VOC's was carried out by Seatech Ltd., Halifax, NS.

Results

Figures 1 to 3 show the painted test pieces prior to immersion in the candidate solvents. An equal number of pipe sections and pipe elbows (coated with white powder epoxy) and brackets and valve covers (coated with black spray epoxy) were immersed in each solvent.

Figures 4 to 8 show the test pieces following 2, 4, 6, 8, and 24 hours immersion in the stripping solvents respectively. The effectiveness of the three strippers following each of the immersion times is discussed below.

2 Hours

Three pipe sections and one elbow were randomly selected and removed from each of the solvents after 2 hours immersion. The test pieces were rinsed with a high pressure water jet and allowed to air dry. The pieces were then inspected and photographed. Test pieces

following a two-hour immersion in the stripping solvents are shown in Figure 4. It can be seen from Figure 4 that the Oakite Stripper SA was effective in removing all of the white powder epoxy paint coating. By comparison, the Fine Organics FO 606 removed approximately 95 % of the paint coating from the pipe sections and the pipe elbow and Turco 5668 removed approximately 70% of the paint coating on the pipe sections and the pipe elbow. These test pieces were not returned to the stripping tanks after being inspected and photographed.

The brackets and valve covers were not removed at this time as the solvents had little effect on the paint.

<u>4 Hours</u>

Test pieces following a four-hour immersion in the stripping solvents are shown in Figure 5. It can be seen from Figure 5 that Oakite Stripper SA and Fine Organics FO 606 were 100% effective in removing the white powder epoxy paint from the surfaces of the pipe sections and the pipe elbows. Turco 5668 was approximately 95 % effective in removing the white powder epoxy paint from the surfaces of the pipe sections and pipe elbows.

<u>6 Hours</u>

After six hours of immersion the remaining powder epoxy coated pipe sections and pipe elbows were removed from the candidate strippers. The brackets coated with black spray epoxy were also removed at this time for evaluation. Photographs of the test pieces removed from the candidate solvents are shown in Figure 6. It can be seen from Figure 6 that Oakite Stripper SA was 100% effective in removing both the white powder epoxy and the black spray epoxy coatings from all test pieces. Fine Organics FO 606 was determined to be 100% effective in removing the white powder epoxy coating and approximately 80% effective in removing the black spray epoxy coating. There was no change in the stripping effectiveness of Turco 5668 for the white powder epoxy coating compared to the test pieces immersed for four hours. Turco 5668 was determined to be less than 5% effective in removing the black spray epoxy. At this time the brackets

coated with the black spray epoxy were returned to the stripper baths for an additional 2 hours.

8 Hours

After 8 hours immersion, the black epoxy coated brackets were again removed from the strippers, rinsed and evaluated. The black epoxy coated valve covers were also removed for evaluation. Photographs of the test pieces are shown in Figure 7. It can be seen from Figure 7 that Oakite Stripper SA was 100% effective in removing the black spray epoxy coating from the bracket and valve cover. Fine Organics FO 606 was approximately 90% effective in removing the black spray epoxy coating from the bracket and valve cover. The stripping effectiveness of Turco 5668 had not improved from the evaluation made at 6 hours. That is, it had removed less than 5% of the black spray epoxy from the bracket and valve cover.

The Oakite Stripper SA evaluation was terminated. The test pieces removed from Fine Organics FO 606 and Turco 5668 were returned to the stripping tanks and left overnight.

The VOC monitors worn by the Chemical Cleaning Shop personnel were collected by Preventive Medicine for analysis.

24 Hours

A photograph of the test pieces following 24 hours immersion is shown in Figure 8. Comparison of Figures 7 and 8 indicates that the further 16 hours immersion resulted in a slight increase in the amount of black spray epoxy removed by Fine Organics FO 606. There was no change in the amount of paint remaining on the bracket and valve cover immersed in Turco 5668. At this point the evaluation was terminated because it was stated by the Chemical Cleaning Shop personnel that 24 hours is the maximum time a piece would be immersed in a solvent.

Summary of Results

The results of the immersion testing are summarized in Table 2. Oakite Stripper SA, as expected, was 100% effective in removing both the white powder epoxy (2 hours) and the black spray epoxy (6 hours) coatings. Fine Organics FO 606 was also 100% effective in removing the white powder epoxy coating but took 4 hours as compared to 2 hours for the methylene chloride based stripper. Fine Organics FO 606 was not 100% effective in removing the black spray epoxy after 24 hours immersion. However, it did remove 90% of this coating in 8 hours. Turco 5668 was the least effective of the strippers. It removed 95% of the white powder epoxy within 4 hours. However, further immersion time did not improve the effectiveness of this stripper. Turco 5668 had very little effect on the black spray epoxy painted test pieces (less than 5% paint removed) after 24 hours immersion.

Table 2. – Effectiveness of candidate paint strippers at timed intervals.

	2 Hours	4 Hours	6 Hours	8 Hours	24 Hours
Stripper SA	100%	100%	100% (White) 100% (Black)	100% (Black)	NA
Fine Organics FO 606	95%	100%	100% (White) 90% (Black)	90% (Black)	90% (Black)
Turco 5668	70%	95%	95% (White) <5% (Black)	<5% (Black)	<5% (Black)

The results of the VOC analyses, which are shown in Table 3, indicate that there were no serious health concerns associated with the use of any of the products tested in the Chemical Cleaning facility in Building D-200. The analysis technique (gas chromatography/ mass spectrometry) identifies and quantitates the 33 compounds listed in Table 3. In addition any VOC, which produces a measurable peak, will be identified and quantitated. N-methylpyrrolidone was not present on any of the dosimeters at a detectable level. This can be attributed to the lower volatility of N-methylpyrrolidone as well as the quality of the air filtration system in this facility and to the diligence and safe working practices demonstrated by shop personnel.

Table 3. – Results of VOC analyses of passive dosimeters.

Compound Name	TLV[1]	Date Received 24-09-99 OVM serial No. JT9000	JT9021	JT9232	Date Received 01-10-99 OVM serial No. SZ7863	SZ7893	SZ7912
benzene	1.6	N.D	N.D	N.D	N.D.	N.D.	N.D.
toluene	188	N D.	N D.	N D.	0.07	0.12	0.14
ethylbenzene	434	N.D.	N D.	N D.	N.D.	N.D.	N.D.
xylenes (total)	434	N D.	N D.	0.04	0.04	0.05	0.05
styrene	85	N.D.	N.D.	N.D.	N.D.	N.D.	N D.
isopropylbenzene	246	N.D	N.D	N.D.	N.D.	N.D	N.D
3-ethyltoluene	N/A	N.D	N.D	N D.	N D	N.D.	N.D
1,3,5-trimethylbenzene	123	N.D	N.D	N D.	N D.	N D	N D
1,2,4-trimethylbenzene	123	N D	N.D	N D.	N.D.	N D.	N D
n-hexane	176	N.D	N D	N D	N.D	N.D	0 09
n-heptane	1640	N.D	N D	N D.	N.D	N.D.	N.D.
n-octane	1400	N D	N D.	N D	N D.	N.D.	N.D
n-nonane	1050	N.D	N D.	N.D	N.D.	N.D.	N.D
n-decane	N/A	N.D	N.D.	N.D.	N.D.	N D	N.D
n-undecane	N/A	N D	N.D	N D.	N D.	N.D.	N D.
n-dodecane	N/A	N.D	N D	N D	N D	N D.	N D
2,2,4-trimethylpentane	N/A	N D	N D	N.D	N D	N.D	N D
methylcyclohexane	1610	N D	N.D	N D	N D.	N D	N.D.
chloroform	49	N D.	N D	N D	N.D.	N D	N D
1,1,1-trichloroethane	1910	N.D.	N D.	N D	N.D.	N D.	N D.
carbon tetrachloride	31	N.D	N.D.	N D	N D	N D	N D.
trichloroethylene	269	N D	N.D	N D	N D.	N.D	N D.
1,1,2-trichloroethane	55	N D	N D	N.D	N.D	N D	N.D
tetrachloroethylene	170	N D.	N.D.	N.D	N.D.	N.D	N D
chlorobenzene	46	N.D	N D.	N.D.	N.D.	N.D	N D.
1,4-dichlorobenzene	60	N.D.	N D	N D.	N.D.	N D.	N D
1,2-dichlorobenzene	159	N D.	N D	N.D.	N.D.	N.D	N D
Uncalibrated Compounds*	N/A	0.18	0 06	0.06	N.D	N D	N D
ethyl acetate	1440	N.D	N D	N D	N D.	N D	N D
4-methyl-2-pentanone (MIBK)	205	N D	N D	N D.	N.D.	N D	N D
2-hexanone	20	N D	N D.	N.D	N D	N D	N D
D-limonene	N/A	N.D	N D	N D	N D	N D	N D
methylene chloride	50	0.16	0 15	0 53	0.30	2 01	1 03

[1] Threshold Limit Value, toxic limit for industrial workers based on 8 hour exposure (TWA). Values given are from American Conference of Governmental Industrial Hygienist, "1996-1997 Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices", ©1996 ACGIH, ISBN: 1-882417-02-8

N/A, Information Not Available
N D., Not Detected
* Uncalibrated Compounds, quantified as toluene equivalents.

Method Detection Limit (mg/m^3) depends on VOC in question, and dosimeter exposure This is typically 0 01 mg/m^3 for an 8 hour exposure period.

Analysis results provided by SEATECH Ltd , Halifax NS

The cost of the three cleaners used in this study were Oakite Stripper SA $6.97 CND/L, Fine Organics FO 606 $12.50 CND/L ($35.35 US/US gallon), and Turco 5668 $13.30 CND/L.

Performance of Turco 5668

The lack of effectiveness of Turco 5668 as a paint stripper in Phase II of this project was not expected. In Phase I of this project Turco 5668 was ranked number 3 of the 7 candidate paint strippers with an overall performance effectiveness of 96% on powder epoxy, spray epoxy and polyurethane coatings. Investigation of the MSDS supplied with this product showed that the formulation had changed between Phase I and Phase II. The MSDS for Turco 5668 supplied for Phase I stated a concentration of NMP of 40-60 %. The MSDS supplied with the Turco 5668 for Phase II stated a concentration of NMP of only 10-30 %. This suggests that the stripping effectiveness of commercial cleaners containing NMP is dependent on the concentration of NMP in the cleaner. That is, cleaners containing 40-60% NMP are more effective than Cleaners containing 10-30% NMP.

Replacement Protocol for Methylene Chloride Based Paint Removers

DREA Dockyard Laboratory was also requested to comment on protocol for choosing a replacement for methylene chloride based paint strippers. The US Army has produced a document, as part of its Solvent Substitution Program, which is a Standard Protocol for Selecting General Cleaning Agents and Processes. This document is presented in three chapters. Chapter one provides a general introduction to the issues regarding cleaning solvent substitution and provides some background in the development of this protocol. Chapter two presents the essential tools needed to understand the protocol, and also presents a detailed explanation of the fundamentals of executing and using the protocol. Chapter three presents the step by step procedures for using this protocol. This document has been reviewed and it is felt that it can be adopted directly by NDHQ for use in the CF. A copy of this document is attached as Appendix B.

Conclusions

The evaluation indicates that Fine Organics FO 606 is the best candidate (of the seven selected for evaluation in Phase I) to replace Oakite Striper SA (methylene chloride).

There are, however, several drawbacks to the replacement of Oakite Stripper SA with Fine Organics FO 606. These include supply source and cost. Fine Organics FO 606 is not available from a Canadian supplier and therefore must be imported from the United States. Fine Organics FO 606, at $12.50/L, is also considerable more expensive than Oakite SA at $6.97/L.

References

1. Environmentally Sustainable Defence Activities, Department of National Defence, Ottawa, December 1997.

2. Paint Strippers – Methylene Chloride/Dichloromethane Based, Health Canada, 1 December 1999.

3. DREA/CR/98/432, "Evaluation of Candidate Solvent Based Paint Strippers for the Replacement of Methylene Chloride Based Paint Strippers, P.Fewer and C. MacGregor, June 1998, Prepared by SEATECH Limited, Halifax, Nova Scotia (CAN).

4. D-23-003-005/SF-002, Specification for Maintenance Painting of HMC Ships, Low Sheen External Epoxy Coating, 01-31-1994.

Figure 1. – Photograph of test pieces prior to immersion in Oakite Stripper SA.

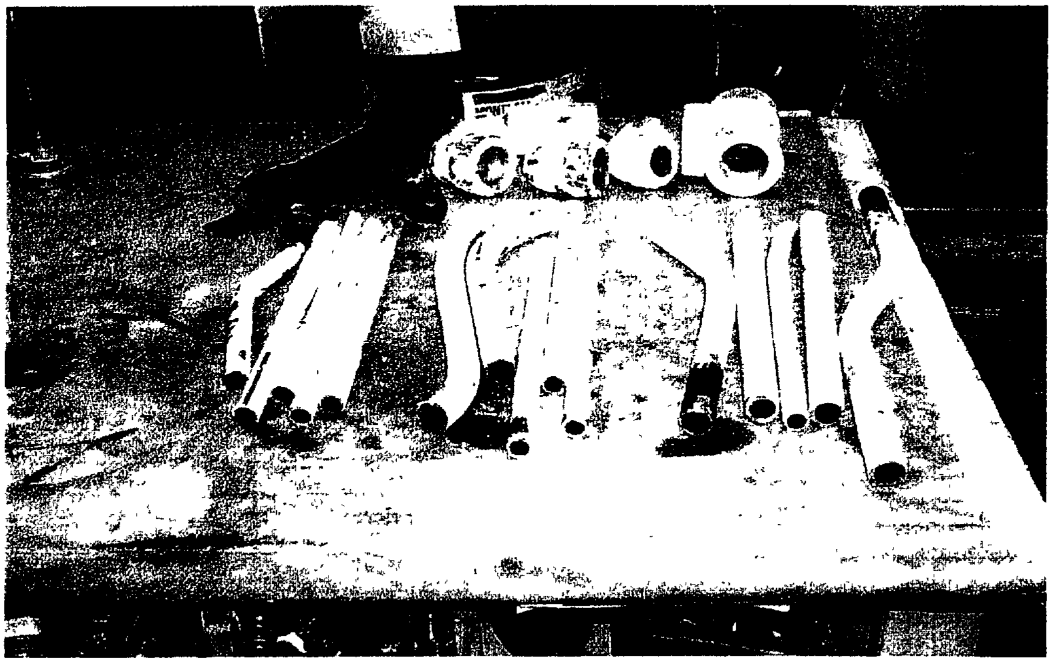


Figure 2. – Photograph of test pieces prior to immersion in Fine Organics FO 606

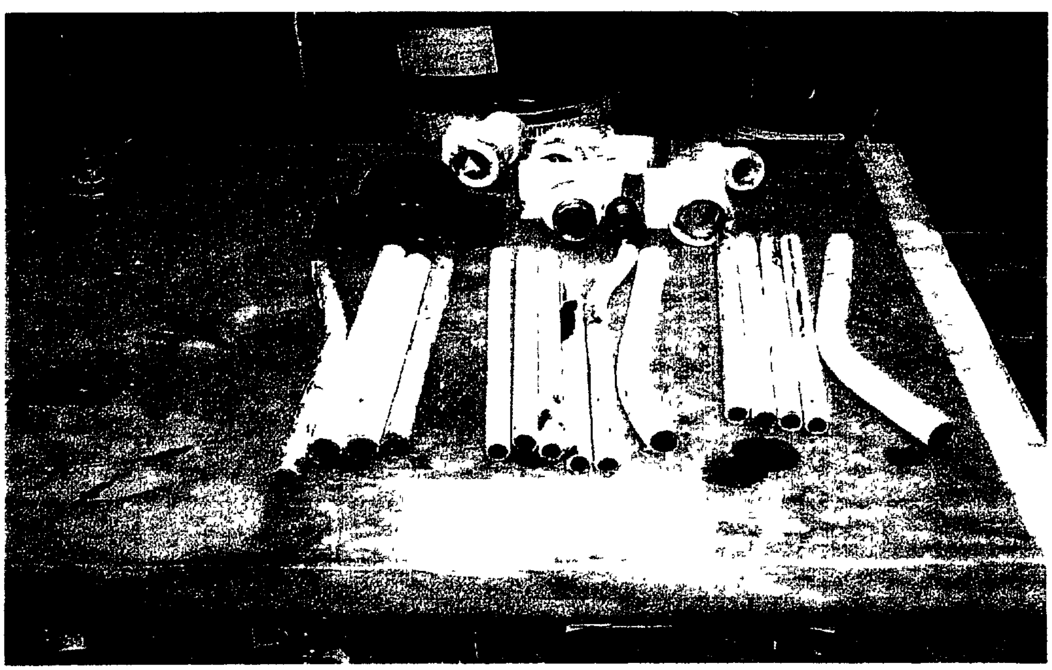


Figure 3. – Photograph of test pieces prior to immersion in Turco 5668.

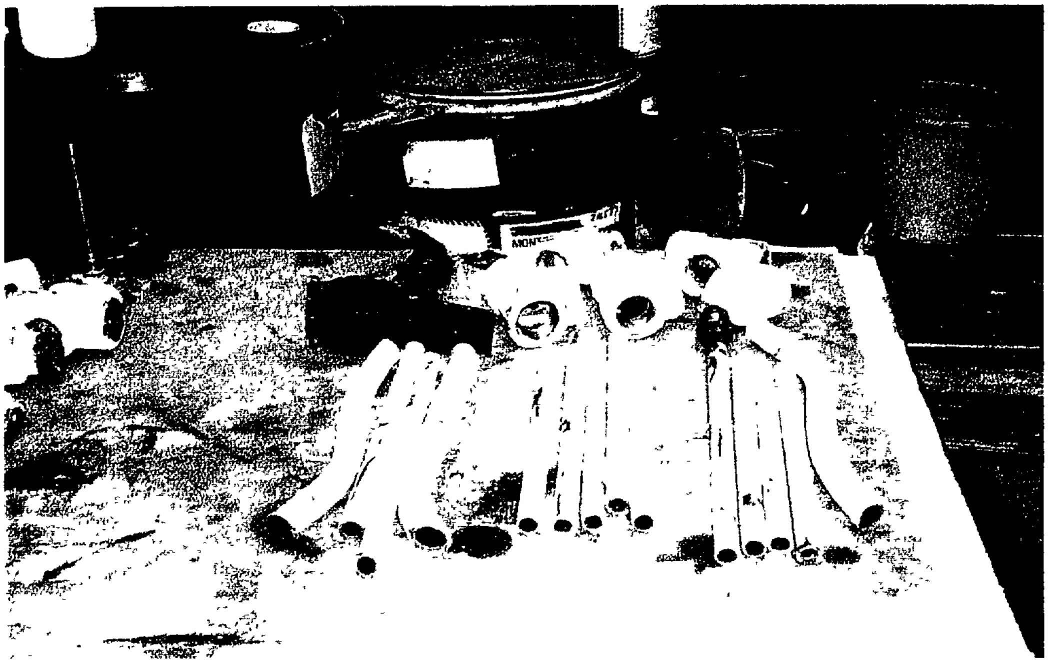


Figure 4 – Photograph of test pieces removed from paint strippers after 2 hours immersion.

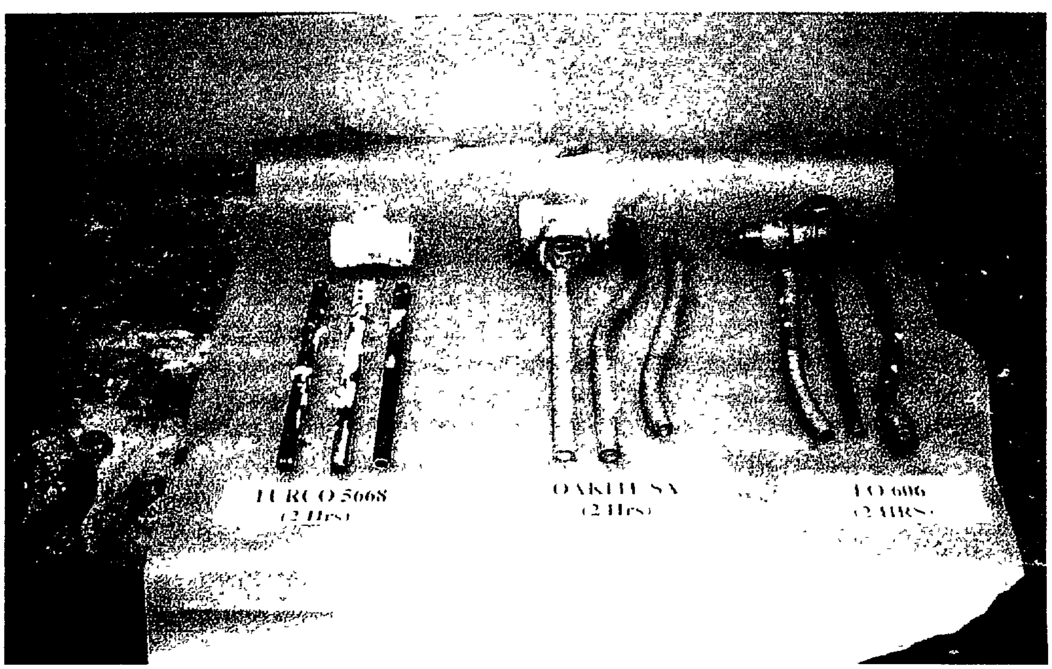


Figure 5. – Photograph of test pieces removed from paint strippers after 4 hours immersion.

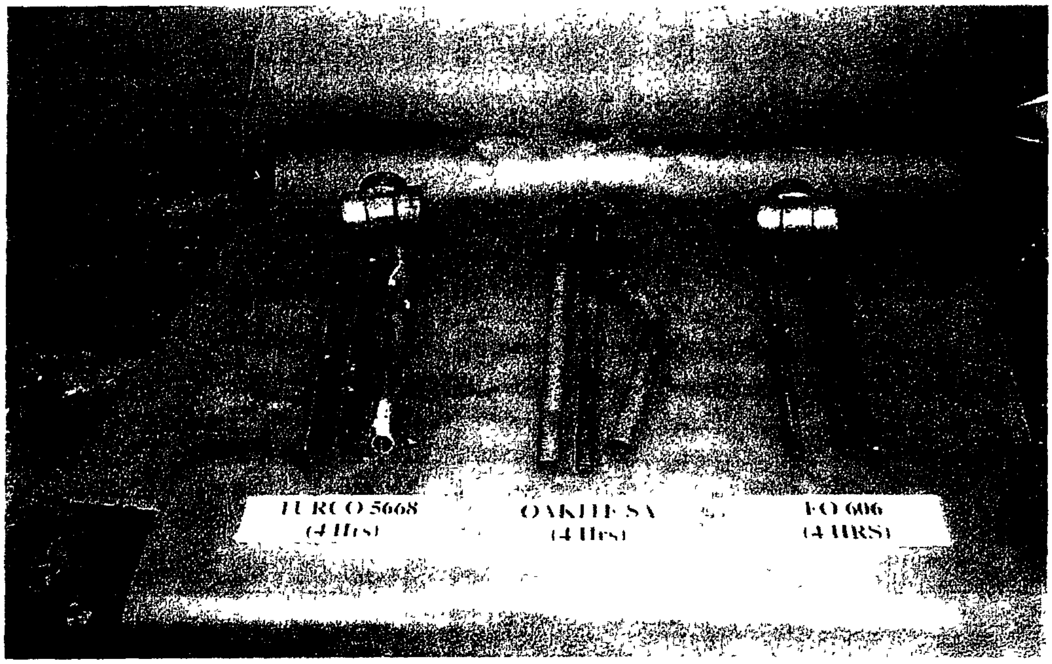


Figure 6. – Photograph of test pieces removed from paint strippers after 6 hours immersion. (note the effectiveness of paint strippers on black epoxy paint on brackets)

Figure 7. – Photograph of black epoxy painted test pieces removed from paint strippers after 8 hours immersion.

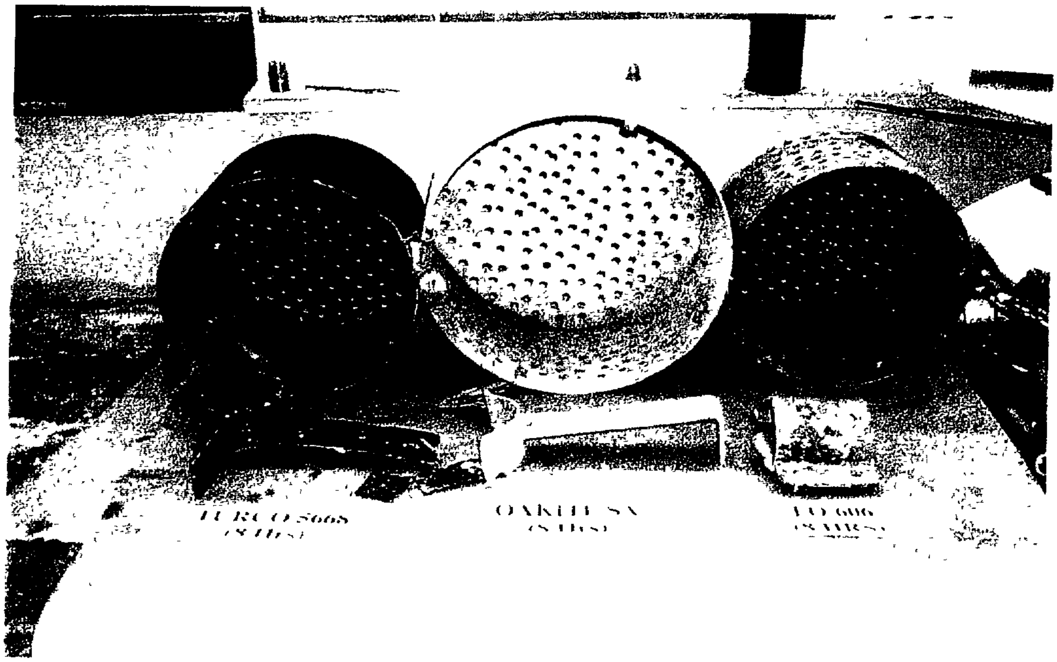
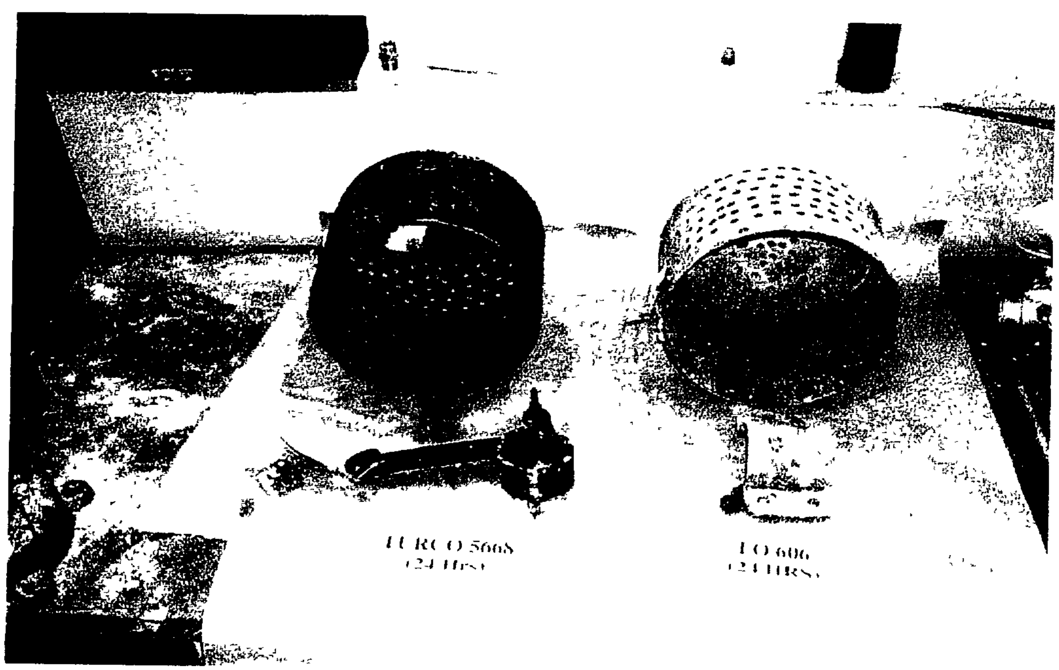


Figure 8. – Photograph of black epoxy painted test pieces removed from paint strippers after 24 hours immersion Oakite Stripper SA was not included at 24 hour interval as pieces had been completely stripped at 8 hours.



Appendix A

Material Safety Data Sheets for Fine Organics FO 606, Turco 5668 and Oakite Stripper SA

fine organics corporation

HAZARD RATING
4 = EXTREME
3 = HIGH
2 = MODERATE
1 = SLIGHT
0 = INSIGNIFICANT

Fire 1, Health 2, Reactivity 0, Special 0

PAGE. 1
DATE PRINTED: 7/2/97
MSDS NO. 442-95

FO®606 w Seal

MATERIAL SAFETY DATA SHEET

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

PRODUCT NAME:	**FO®606 w Seal**
CHEMICAL FAMILY:	Organic Stripper
CHEMICAL NAME:	Stripper
PRODUCT DESCRIPTION:	Hot Tank Stripper With Seal Oil

MANUFACTURER:
FINE ORGANICS CORPORATION
205 MAIN ST.
LODI, NJ 07644
800-526-7480

EMERGENCY TELEPHONE NUMBERS:
(201) 472-6800 24 hours Everyday

CHEMTREC: (800) 424-9300 24 hours Everyday

2. COMPOSITION/INFORMATION ON INGREDIENTS

HAZARDOUS INGREDIENTS.	% w/w	CAS#
Ethanolamine	> 15	CAS# 141-43-5
N-Methylpyrrolidone	> 60	CAS# 872-50-4

OSHA HAZARDS (29 CFR1910.1200): N-Methylpyrrolidone is SARA 313 reportable only if using more than 10,000 pounds per calendar year. Equivalent to 38 x 55 gallon drums of FO 606 (2090 gallons).

	OSHA		ACGIH	
	TWA	STEL	TWA	STEL
Ethanolamine	3ppm	6ppm	3ppm	6ppm
N-Methylpyrrolidone	100ppm	N.E.	N E	N.E.

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW:
Yellow liquid - Corrosive to skin and mucous membranes, does not corrode metals - Wear Self Contained Breathing Apparatus for fire

POTENTIAL HEALTH EFFECTS

INHALATION.
High vapor concentrations may be irritating to the eyes,nose and respiratory tract.May cause headaches,dizziness and nausea.Use with adequate ventilation.

EYE CONTACT.
Contact will cause irritation and/or burns.

SKIN CONTACT.
May cause skin irritation and/or dermatitis.

INGESTION:
May cause pulmonary damage, if aspirated into the lungs.

CHRONIC:
Repeated inhalation may cause lung damage.

CARCINOGENICITY:

PHASE I

MATERIAL SAFETY DATA SHEET

1. PRODUCT INFORMATION

TRADE NAME	: 5668
MANUFACTURER	: DEANE AND COMPANY 190 ONEIDA DRIVE, POINTE-CLAIRE, QUEBEC
ISSUED	: 96-05-13
SUPERSEDES	: 93-11-29
DOCUMENT NO	: 5668-C
SUPPLIER	: DEANE & COMPANY PHONE NO: (514) 697-3730
EMERGENCY PHONE NO	: CANUTEC (613) 996-6666
PRODUCT USE	: PAINT STRIPPER

2. HAZARDOUS COMPONENTS

INGREDIENT	C.A.S. NO.	PERCENT	SPECIES/ROUTE LC_{50} LD_{50}
Potassium hydroxide	1310-58-3	1-5	LD_{50} 1.23g/kg, oral, rat LC_{50} not available
Monoethanolamine	141-43-5	30-60	LD_{50} 10.2g/kg, oral, rat LC_{50} not available
N-Methylpyrolidone	872-50-4	10-30	LD_{50} 4.2g/Kg, oral, rat

SOURCE OF DATA: MERCK INDEX TENTH EDITION

3. PHYSICAL DATA

PHYSICAL STATE:	Liquid
BOILING POINT:	Approx. 120°C.
VAPOR PRESSURE:	Approx. 10mm
VAPOR DENSITY	Approx. 3
EVAPORATION RATE:	Approx. 0.1
SOLUBILITY IN WATER:	75%
SPECIFIC GRAVITY:	1.03
PERCENT VOLATILE:	Approx. 30
VOLATILE ORGANICS:	Approx. 30%
pH:	11-12
VISCOSITY:	Not available
APPEARANCE AND ODOR:	Straw colored liquid, mild ammonia odor.
ODOR THRESHOLD:	Not available
FREEZING POINT:	Not available

MATERIAL SAFETY DATA SHEET

PHASE II

1. PRODUCT INFORMATION:

TRADE NAME	:	5668
MANUFACTURER	:	Deane & Company, 190, Oneida, Pointe-Claire (Quebec) H9R 1A8
SUPERSEDES	:	5668-D
DOCUMENT #	:	5668-E
SUPPLIER	:	DEANE & COMPANY
PHONE #	:	(514) 697-3730
EMERGENCY PHONE #	:	CANUTEC: (613) 996-6666
PRODUCT USE	:	PAINT STRIPPER

2. HAZARDOUS COMPONENTS:

INGREDIENT	C.A.S.#	PERCENT	SPECIES/ROUTE LC_{50} LD_{50}
Potassium hydroxide	1310-58-3	1-5	LD_{50} 1.23g/Kg, oral, rat LC_{50} not available
Monoethanolamine	141-43-5	30-60	LD_{50} 10.2g/Kg, oral, rat LC_{50} not available
N-Methylpyrolidone	872-50-4	15-40	LD_{50} 4.2g/Kg, oral, rat LC_{50} not available
Oil, naphtenic	64742-52-5	10-20	Not available

SOURCE OF DATA : *MERCK INDEX TENTH EDITION*

3. PHYSICAL DATA:

PHYSICAL STATE	:	Liquid
BOILING POINT (°C)	:	Approx. 120°C
VAPOR PRESSURE (mmHg)	:	Approx. 10 mm
VAPOR DENSITY (air = 1)	:	Approx. 3
EVAPORATION RATE (nBuAc=1)	:	Approx. 0.1

Oakite

5540

MATERIAL SAFETY DATA SHEET

PRODUCT CODE: 5540
OAKITE STRIPPER SA
108-XD-159

(W.M)

8010 21 853 8348

HMIS 3 1 0 H
WHMIS E

SECTION I - PRODUCT IDENTIFICATION

ADE NAME	OAKITE STRIPPER SA	EMERGENCY TELEPHONE NUMBER:
EMICAL NAME		(800) 424-9300 (CHEMTREC)
D SYNONYMS	NA-Mixture	
NUFACTURER'S NAME		
) TELEPHONE NO.	OAKITE CANADA LIMITED (908) 464-6900 (8am-5pm)	
DRESS	115 East Drive Bramalea Ontario L6T 1B7	

SECTION II - HAZARDOUS INGREDIENTS

	CAS NO.	% WT/WT	TLV	UNITS
hylene chloride	0000075092	85-95	50	ppm
mic acid	0000064186	<5	5	ppm
ycolic acid	0000079141	<5	n.av	
-hazardous ingredients		Bal.		

(50) (methylene chloride): 2136 mg/Kg (orl-rat)
(formic aicd): 1100 mg/Kg (orl-rat)
50) n.av.

components of this material are on the Domestic Substances List (DSL).

SECTION III - PHYSICAL DATA

LING POINT (F)	n.av.	SPECIFIC GRAVITY (H20=1)	1.299
EZING POINT	n.av.	Bulk Density	10.8 lb/gal
POR PRESSURE (mm Hg)	n.av.	PERCENT VOLATILE	
POR DENSITY (Air=1)	>1	BY WEIGHT(%) Excludes H20	85-95
UBILITY IN WATER	Moderate	PH	n.av.
ER/OIL DISTRIBUTION	n.av.	PH (concentrate)	n.av.
PEARANCE AND ODOR	Black liquid; pungent odor.	EVAPORATION RATE (Ether=1)	<1

ap. - Not Applicable n.av. -Not Available

Appendix B

United States Army Solvent Substitution Program

EnviroSense

U.S. Army Solvent Substitution Program - Chapter One - Draft

Introduction

1.1 Overview

The Army Standard Protocol for Selecting General Cleaning Agents and Processes is presented in three chapters. Chapter one provides a general introduction to the issues regarding cleaning solvent substitution and provides some background on the development of this protocol. Chapter two presents the essential tools needed to understand the protocol, and also presents a detailed explanation of the fundamentals of executing and using the protocol. Chapter three presents the step-by-step procedures for using this protocol.

1.1.1 Purpose of Army Standard Protocol

The purpose of establishing an Army standard protocol for selecting cleaning agents and processes is to standardize the approach to solvent substitution efforts by establishing **minimum requirements** for testing which must be met by all replacement or alternative cleaning products. The procedures presented in this protocol are the same procedures which are featured in the Standard Guide for Selecting Cleaning Agents and Processes, currently being developed by the American Society for Testing and Materials (ASTM). When the ASTM Standard Guide is published (likely in 1997), it will supersede this guidance. No protocol, however, whether Army or ASTM, is a substitute for good engineering practices.

1.1.2 Why are we Replacing Cleaning Solvents?

Cleaning of Army equipment is one of the most prominent manufacturing or maintenance activities performed in the Army. At times, the cleaning requirements are simply for cosmetic purposes or to remove gross amounts of dirt and grime accumulated from field activities. At other times, the cleaning requirements are for critical applications, such as the cleaning of aircraft flight safety parts prior to liquid dye penetrant inspections, or critical cleaning processes in munitions manufacturing. These two groups of cleaning tasks have widely varying requirements for cleanliness and cleaners. For the first group a mild detergent may be sufficient, whereas for the second group an aggressive solvent and multiple process steps may be required to provide sufficient levels of cleanliness.

Technical manuals (TMs), depot maintenance work requirements (DMWRs), and other process documents contain specific requirements for the cleaning of components and materials. These technical documents often contain references to hazardous or environmentally unacceptable solvents, including ozone depleting chemicals (ODCs). These materials were selected in the past because of their cleaning effectiveness. Starting in the early 1990s, with the then-impendingproduction ban on ODCs, an increased scrutiny was also placed on other hazardous or environmentally unacceptable materials, such as volatile organic compounds (VOCs). Thus the need has arisen to eliminate requirements for many of these highly effective, but environmentally unacceptable products, and determine the best economically feasible, environmentally acceptable, replacements, which are also safe from the worker health and safety

standpoint.

1.1.3 Selection/Replacement Basics

When selecting an environmentally acceptable alternative cleaning agent, there are two critical requirements:

1. to ensure that the new agent gets the component ***clean enough*** for subsequent processing steps, and

2. to ensure the new agent ***does not compromise the structural integrity*** of the component being cleaned (or any other adjoining components).

To date, there have been a number of Army efforts designed to replace ODCs or other hazardous solvents in technical documents or maintenance processes. Some of these efforts included laboratory and field testing of replacement products, as well as toxicological screening. Others however, relied on anecdotal information, a manufacturer's claim, or other potentially unreliable data. This has often resulted in the selection of a replacement agents based on insufficient data. A single standard approach must be pursued.

Keep in mind that there are other issues which could be critical to the cleaning process which are not being specifically addressed by this protocol.

1.1.4 Adoption of a Standard Approach

The primary purpose of this protocol is to standardize the approach to solvent substitution efforts, by defining the requirements for the level of cleanliness and the material compatibility for general cleaning applications. This protocol will allow the design engineers to select an effective cleaner, for the cleaning task at hand, based on standard evaluation procedures and sound engineering principles and practices. It must be stressed that these requirements are intended to be **minimum standards**, applied across all commands. If the engineers at a particular command believe that there are special cleaning requirements under their cognizance which require additional tests or evaluations, they should certainly specify them.

Under this standard approach, the technical requirements for the cleaning task are established by using a series of matrices, then the engineer is directed to a set of recommended cleaning products which have met those necessary minimum requirements. Other informationmay be required for the industrial/maintenance engineer to make the final decision for his particular situation. These factors may include:

- Toxicological information
- Cost
- Flash point
- Disposal requirements
- Odor
- pH Values
- Personal protective equipment
- Worker Health and Safety

These factors should also be evaluated, and compared only between those products which first meet the technical requirements for the cleaning task at hand. A more detailed discussion of these secondary evaluation criteria can be found in Chapter Two.

1.2 Scope of the Protocol

This specific protocol is geared at general industrial and field cleaning. The reason for this limitation is that general cleaning requirements represent the greatest portion of the hazardous materials problems associated with cleaning in the U.S. Army. Other technical knowledge must be brought to bear on solving the more specific cleaning problems, such as:

- Precision Cleaning
- Electronics Cleaning
- Optical Cleaning
- Paint Removal
- Oxygen Cleaning
- Sealant and Adhesive Removal

Some of these topic may be addressed by future guidance using the approach presented in this protocol to ***re-engineer*** the process to determine the reason a particular activity is being performed, thus possibly eliminating certain "problematic" processing steps.

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Last Updated: November 19, 1996

EnviroSense

U.S. Army Solvent Substitution Program - Chapter Two - Draft

Program Basics

2.1 Cleaning Applications and Materials

The execution of the protocol requires the engineer to make two determinations:

1. Why is the component being cleaned?; and
2. What is/are the material(s) of the component to be cleaned?

2.1.1 Cleaning Activities

The following **reasons for cleaning** represent broad processing categories and the users of this protocol should feel free to use one of these descriptions on a best-fit basis for other similar applications.

2.1.1.1 Pre-cleaning

Pre-cleaning is performed to remove gross soil from a component to avoid contamination of the follow-on cleaning processes. Typically this is performed by steam cleaning, brushing, scraping, pre-soaking, or pressurized spray cleaning with already-contaminated cleaning solutions.

2.1.1.2 Cosmetic cleaning

Cosmetic cleaning may be required when cleaning a component or surface after use or dis-assembly. Although no immediate maintenance action follows, it may be necessary to facilitate subsequent handling of the part during other maintenance procedures. Cosmetic cleaning may also be necessary for cleaning a component to make it look aesthetically pleasing, or to facilitate easier assembly.

2.1.1.3 Pre-paint cleaning

Pre-paint cleaning is a requirement to clean a component or surface prior to the application of paint or primer, and is performed to aid coating adhesion. Various coatings will require different degrees of surface cleanliness.

2.1.1.4 Pre-plate cleaning

Pre-plate cleaning is a requirement to clean a component or surface prior to plating, welding, anodizing, the application of metal spray, or similar surface finishing or chemical treatment, and is performed to aid adhesion of the surface finish. Different plating processes willrequire varying degrees of surface cleanliness.

2.1.1.5 Pre-bond cleaning

Pre-bond cleaning is a requirement to clean a component or surface prior to the application of an adhesive or sealant for the express purpose of bonding that surface or component to another. This category of cleaning is intended to include the critical cleaning requirements for structural bonding.

2.1.1.6 Pre-Non Destructive Test (NDT) cleaning

The most critical NDT cleaning requirements are for florescent dye penetrant inspections. This is because all of the cracks in a part that would be identified by this NDT process must be clean enough to allow the fluorescent dye to penetrate into them, thereby facilitating detection. Levels of cleanliness suggested in this protocol in the NDT category are for fluorescent dye penetrant inspection. The user of this protocol may lower this cleanliness requirement for other forms of NDT, as experience dictates. Care must be exercised so that for magnetic particle inspection, the working fluid will not "de-wet" from the part being inspected. Therefore the cleaning process selected must achieve a level of cleanliness to prevent de-wetting of the working fluid. Cleanliness levels may also be adjusted for eddy current inspection as experience dictates.

2.1.1.7 Special Cleaning: Hydraulic parts and bearings

Hydraulic components and bearings require a high level of cleanliness due to close tolerances, or other physical parameters that cannot be satisfied by other cleanliness requirements.

2.1.2 Materials

Most of the general and industrial cleaning activities will be performed on some type of metal, composite or plastic surface. The reason that the material of the component is a critical factor is because each material has certain physical properties which when combined with the chemical or physical properties of a cleaning agent or process, could make that material subject to degradation. This material degradation can take the form of cracks, corrosion, or small impingements which could lead to the premature replacement or failure of the component. Table 2-1 lists the materials which have been selected by this program as being representative of the vast majority of component materials which are subject to cleaning during U.S. Army maintenance. If a specific material is not listed in table 2-1, technical engineering judgement must be applied to determine the critical material properties which would dictate the selection of cleaning agents and processes. As experience and technical knowledge dictates, these other materials may be grouped with those listed.

Table 2-1. Typical Component Materials

Carbon and Low Alloy Steel	Metal Honeycomb
Super Alloy - Cobalt	Rubber Compounds
Super Alloy - Nickel	Thermoset Plastics
Super Alloy - Titanium	Thermo Plastics
Stainless Steel	Acrylics
Iron	Polycarbonates
Aluminum	Optics
Magnesium	Polyamide wiring (Insulation)
Brass	Leather and Fabrics
Bronze	Coated Surfaces
Copper and its Alloys	Polysulfides

The material of the component being cleaned is a critical, and much overlooked element in selecting the appropriate cleaning technology and product. One cleaner may be very effective and safe to use on metals, but very harmful to rubber or plastics. A cleaner might work well on an aluminum part, but may cause stress corrosion cracking in titanium parts. Not only should the material of the component be known, but the material of the adjacent parts should be considered when there is a possibility they will be exposed to the cleaning agent during the cleaning operation.

The most effective way to ascertain the material of a given component may be for a knowledgeable person to examine or analyze the part in question. Another effective way to ascertain the material of a component is to analyze the drawing of the component, or contact the component manufacturer.

2.2 Definitions/Terminology

A number of terms are used throughout this document to explain certain portions of protocol execution, or to describe certain aspects of the protocol. Some of these terms may have acquired differing meanings for different individuals, therefore it is important to define them as they are to be understood within the confines of this document:

2.2.1 Cleaning Efficiency

The measure (by percentage) of how well a cleaning agent is able to clean a substrate.

2.2.2 Cleaning Effectiveness Factor (CEF)

From ASTM G-122. The cleaning effectiveness factor indicates the fractional contaminant that

was removed during cleaning.

2.2.3 Level of Cleanliness

The degree to which a part must be cleaned in order to successfully perform the next manufacturing or maintenance procedure.

2.2.4 Specific Tests

Standard tests for materials compatibility.

2.2.5 Basic Tests

Standard evaluation criteria to ascertain various chemical, physical and material safety properties of a cleaning agent.

2.2.6 Test Protocol

A combination of one or more Specific Tests which must be performed on a cleaning agent to ensure its use will not damage a particular material.

2.2.7 Aqueous Cleaning Agent

A cleaning medium that uses water as the primary cleaning component. Additive products are used in these agents primarily to prepare the water as a vehicle which can capture or remove hydrophobic soils from the dirty component. These additives may also be used to reduce the corrosivity of the water, increase wetability, emulsify soils, add a dye marker, or change the pH of the water.

2.2.8 Semi-aqueous Cleaning Agent

A cleaning medium that uses a concentrate chemical to remove soils, which is water soluble. The typical semi-aqueous cleaning process will have a wash step (where the cleaning agent is used), followed by an emulsion rinse, then several water rinses, and finally and drying cycle.

2.2.9 Solvent-Type I

Non-ozone depleting solvents that are not Volatile Organic Compounds (VOCs), Hazardous Air Pollutants (HAPs), or SARA Title III Reportable chemicals.

2.2.10 Solvent-Type II

All other non-ozone depleting solvents which do not fit the description of solvent type-I.

2.3 Reference Documents

Table 2-2 contains a list of documents that are referenced in this protocol. In deference to the tenants of Acquisition Reform, an aggressive attempt was made to reference commercial or industry consensus specifications and standards.

2.4 Detailed Discussion/Additional Guidance

This section contains a detailed discussion of some of the ***key factors*** regarding the use of the protocol.

2.4.1 Reason for cleaning

The reason for cleaning a part most often corresponds to the next maintenance action to be completed. In order to determine the reason for cleaning, analysis of the entire maintenance process must be performed. For example, a task statement in a DMWR may simply say to clean a component using a solvent cleaner. This simple statement provides almost none of the information that is required for making the selection to replace this solvent cleaner. Analysis must be performed on both the past activities, and future maintenance action to be performed on that part to make an accurate determination of the appropriate product and process to be utilized.

Table 2-2. Referenced Documents

Document Number	Title
ASTM-D-56	Test method for Flashpoint by Tag Closed Tester
ASTM-D-59	Test Method for Flash and Fire Point by Cleveland Open Cup
ASTM-D-903	Peel or Stripping Strength of Adhesive Bonds
ASTM-D-1002	Strength Properties of Adhesives in Shear by Tension Loading
ASTM-D-1781	Climbing Drum Peel Test for Adhesives
ASTM-D-1876	Peel Resistance of Adhesives
ASTM-D-2240	Test Method for Rubber Property - Durometer Hardness
ASTM-D-2919	Determining Durability of Adhesive Joints Stressed in Shear by Tension Loading
ASTM-D-3167	Floating Roller Peel Resistance of Adhesives
ASTM-D-3762	Adhesive Bonded Surface Durability of Aluminum (Wedge Test)
ASTM-E-70	Test Method for pH of Aqueous Solutions with the Glass Electrode
ASTM-F-483	Method for Total Immersion Corrosion Test for Aircraft Maintenance
ASTM-F-484	Test Method for Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds

ASTM-F-485	Test Method for Effects of Cleaners on Unpainted Surfaces
ASTM-F-502	Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces
ASTM-F-519	Method for Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals
ASTM-F-1104	Test Method for Preparing Aircraft Cleaning Compounds, Liquid Type Water Base, for Storage Stability Testing
ASTM-F-1110	Test Method for Sandwich Corrosion Test
ASTM-F-1111	Corrosion of Low Embrittlement Cadmium Plate by Aircraft Maintenance Chemical
ASTM-G-93	Cleaning Methods for Material and Equipment Used in Oxygen-Enriched Environments
ASTM-G-121	Preparation of Contaminated Test Coupons for the Evaluation of Cleaning Agents
ASTM-G-122	Standard Test Method for Evaluating the Effectiveness of Cleaning Agents
SAE ARP 1795A	Test for Stress Corrosion of Titanium Alloys
AMS 3204/AMS 3209	Test for Rubber Compatibility
MIL-C-85570	Test for Polyamide Wire Compatibility
MIL-C-87937B	Various Tests for: Foaming Properties, Toxicity, Biodegradability, Volatility, Residue Rinsibility
FED STD 536/6701	Test Method for Cleaning Efficiency

It is sometimes assumed that because an aggressive cleaner was used in a cleaning task, an alternative cleaner must be equally as aggressive. This may not be the case. Many times the writers of technical documents did not perform the type of analysis that is required by this protocol, and have settled for using one cleaner for a variety of purposes. Thus, in many cases this turned out to be too aggressive a cleaner, and in other cases, this cleaner may not have been effective enough. Following this protocol will solve that problem.

Although the previous maintenance activity is important, the most critical aspect of determining the reason the part is being cleaned is to identify the next maintenance action or process step. Disassembling a part which was in service, and removing some of the soil to make the part easier to handle, is dramatically different than cleaning immediately prior to liquid dye penetrant inspection. Both the product used, and the process employed are likely to vary based on the reason for cleaning.

The best way to determine the reason for cleaning is to examine the cleaning statement task in the

context of the entire maintenance operation. Consider the following statement:

2.3.2 Clean part with a rag soaked with MEK.

This statement provides little information to allow an engineer to make an informed choice as to a replacement cleaner or process for cleaning the part. This statement, when viewed alone is taken out of the context of the entire maintenance procedure. However, consider the following three statements together.

2.3.1 Remove part from aircraft landing gear.
2.3.2 Clean part with a rag soaked with MEK.
2.3.3 Examine part for cracks using liquid dye penetrant process.

Now there is a basis of information from which an intelligent choice can be made on the appropriate cleaner and process. The part has been removed directly from the weapon system, which means it is likely to have been subject to in-service dirt, grime, etc. And most importantly, this part is to be checked for cracks using liquid dye penetrant inspection techniques, which requires a cleaner capable of removing contamination from potential cracks.

2.4.2 History of the Part

With regard to the history of the part, it is important to analyze where a particular part came from in order to determine what soil the part has been subjected to. Questions to be asked about the history of the part to determine the aggressiveness of the cleaner required include:

- Is the part in the manufacturing process?
- Is the part new out of the box?
- Has this part been subjected to prior maintenance?
- Was the part taken directly out of service?

The answers to these questions may help the user determine the type of soil which must be removed from the component. Soil determination is crucial because the overall cleaning performance of a cleaning agent is usually directly related to the soil being removed. For example, when removing light preservative oil, a cleaner may get the component to a level 5 cleanliness (the cleanest contemplated by this standard). However, when faced with removing heavy hydraulic oil, this same cleaner may only clean the product to a level 3 cleanliness. (See next section for a complete discussion of Level of Cleanliness).

To assist in determining the soil a component may have been subjected to, this standard protocol has developed four classes of soils, which can be found in Table A-1 (Appendix A). The soil class determination is to be used in conjunction with the Level of Cleanliness to provide further confidence that the cleaners selected will perform to the level of cleanliness required.

2.4.3 Level of Cleanliness

Level of Cleanliness is determined on a sliding scale based on how clean the part needs to be for the next maintenance action. Level 1 is the least stringent Level of Cleanliness, while level 5 is the cleanest. Table A-2 (Appendix A) presents the Levels of Cleanliness, the type of inspection required to determine if this criteria has been met, and a description which will assist in making the determination of whether the code standard of cleanliness has been achieved. [The descriptions of the inspections are based on the definitions found in ASTM G-93.]

Once the next maintenance action has been determined, and thus the Level of Cleanliness required, the Cleaning Code (Table A-3, Appendix A) will be used to narrow the choice of potential cleaners. There are potentially many more cleaners that will pass the Wipe test than will pass the ASTM Cleaning standard test, removing more than 95% of the contaminants. This now serves as a starting point for making the determination of the proper cleaning product to select.

2.4.4 Material Compatibility

Material compatibility requirements ensure that the cleaner selected will not damage the material(s) of the component being cleaned. A list of these requirements can be found in Table A-4 (Appendix A). Many of these tests need to be conducted in conjunction with others to ensure material degradation will be prevented. Table A-5 (Appendix A) lists the specific tests required to ensure material compatibility.

To ascertain the test protocol requirements the Cleaning Code Identification Matrix (TableA-3) must again be referenced. Down the left hand column of that table are the 22 different types of materials. Find the material type which most closely represents the material type of the component being cleaned, and follow it across until a match in the Reason for Cleaning column is made. The letter portion of the alpha-numeric code represented in that cell is the test protocol for the material. Entering Table A-5 for the alpha portion of the protocol, the applicable tests to be performed are listed. This action serves to reduce the number of acceptable cleaners which can be used for a given application. For example, three (3) cleaners may be acceptable from the standpoint of meeting the cleanliness requirement, but one (1) of them may cause pitting corrosion on the aluminum component being cleaned. Therefore the field of suitable cleaning products has been narrowed. It must be remembered that none of these tests are necessarily pass/fail. It is left up to the user to determine whether the test results are acceptable.

2.4.5 Initial Selection of Alternate Cleaners

Once the cleaning code has been established, the next task is to determine the field of appropriate cleaners. With the vast number of cleaning products available, knowing what the cleaning effectiveness of them are, along with which materials tests they have been evaluated against, is a daunting task for any one Command or industrial facility. However there are several ways to ascertain this information. Some of the sources include:

- Manufacturer's test results
- Results from an independent laboratory
- Results from other industrial facilities which have conducted testing

In order to facilitate selection of suitable products, a list of testing sources and products which have been tested is currently under construction, and will soon be published.

2.4.6 Environmental Concerns

As more National Environmental Standards for Hazardous Air Pollutants (NESHAPS) are adopted (e.g. aviation standard has already been adopted), the use of conventional technologies which are less environmentally friendly, will require very large investment in emission control equipment. No economic consideration of the economic feasibility of this control equipment is allowed. Therefore, it is incumbent upon the specifier of cleaners to select the most environmentally preferable technology available.

To assist in making this evaluation, Table A-6 (Appendix A) lists four categories of cleaners, ranked in the order of environmental preferability. Preference 1 being the most environmentally preferable choice, while preference 4 is the least. Simply stated, if the user is faced with the choice of selecting between two

acceptable cleaners, one which is semi-aqueous and the other which is a solvent, the semi-aqueous product should be selected, *unless* there areother mitigating circumstances.

2.4.7 Physical and Chemical Properties

All cleaning products have associated chemical and physical properties which must also be taken into consideration before a final selection is made. The weight given to any of these properties is an individual choice which must be made by the engineer at the using site, based on the circumstances of their particular facility. Table A-7 (Appendix A) is a partial list of these properties, and associated Basic Tests which will assist in performing a valid comparison of cleaning products. Table A-7 is not an exhaustive list of possible factors or properties. One or more of these properties may be critical to the operation of a particular user or industrial operation. For example, if there are two acceptable cleaners, one which has questionable toxicity data, the other which has more favorable toxicity data, the engineer should make the decision to use the less toxic substance. Some of the other physical considerations may be the odor of the agent, personal protective equipment required, and other factors such as the procurement and operational costs and the disposal requirements.

2.4.8 Other Technology Considerations

Eliminating unnecessary cleaning steps in the maintenance cycle of that part is also a very viable alternative to achieving pollution prevention goals. For example, if the maintenance documents dictate to clean the part, store the part, and then clean the part again before performing the next maintenance action, this may be a waste of resources. If a part can be economically and effectively cleaned once, and then kept clean by any number of means, this should be done, rather than cycle the part through several process steps which each require cleaning. The no-clean option must always be kept in the forefront of possibilities and must be selected where feasible.

Nothing in this protocol should be construed as limiting the possibility of considering other, more exotic technologies for addressing specific cleaning applications. Exotic technologies such as plasma, pressurized gas, and supercritical fluid cleaning may be preferable alternatives. Abrasive and liquid blasting will also have their applicability, however their use should be considered carefully due to possible generation of significant amounts of hazardous waste. As with the other products, product and process costs, waste handling/disposal costs and even potential capital equipment costs must be carefully analyzed and compared to the more traditional approaches.

2.4.9 Equipment Selection

If considering cleaning products for field operations, then more than likely the cleaningproduct selected will be used for hand-wipe cleaning operations. However, if the cleaning products are for use at an industrial facility, then the options will be much broader, and the shape, size or weight of the part may be the critical parameter. Though there is no attempt to provide a protocol or consideration relative to size and weight, however shape is considered by this protocol. There are three basic shapes (Table A-8, Appendix A). From these three shapes a determination can be made as to which shape most closely represents the parts which are being cleaned. Once the shape of the part has been determined, the most likely cleaning processes which can be used on the part can be identified from the Equipment Selection Table (Table A-9, Appendix A).

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U.S. Army Solvent Substitution Program - Chapter Three - Draft

The Army Standard Protocol

3.1 Initial Product Selection

This section will present a step-by-step approach to the use of the protocol. To select a technically acceptable product to perform a general cleaning task, a five step process has been developed, using a series of tables and matrices. Step 1 is to determine the parameters surrounding the cleaning of the component. Steps 2 is to determine the cleaning code, and step 3 to select an appropriate cleaner. Step 4 is to consider other physical and chemical properties of the cleaning agent, and step 5 is to determine the proper equipment selection.

3.1.1 Step 1: Determine Parameters

- Determine ***reason for cleaning*** (see 2.4.1) by analyzing written maintenance documentation.
- Analyze ***history of the part*** (see 2.4.2) and select the appropriate ***class of soil*** from Table A-1 (Appendix A), the part or component was subjected to.
- Determine ***material(s) of the component*** (see 2.1.2) being cleaned by reviewing component drawings, consulting with maintenance personnel, or direct contact with the manufacturer.

3.1.2 Step 2: Determine Cleaning Code

- Determine ***level of cleanliness*** required (see 2.4.3) by selecting the column in Table A-3 (Appendix A) which corresponds to the reason for cleaning.
- Apply the class of soil (from step 1) to the level of cleanliness.
- Select ***material compatibility*** (see 2.4.4) by selecting the row in Table A-3 which corresponds to the material of the component.
- The corresponding alpha-numeric code is the ***cleaning code***.

3.1.3 Step 3: Select Appropriate Cleaner

- Take cleaning code from step two, and perform ***the initial selection of alternative cleaners*** (see 2.4.5), selecting those cleaners which meet the requirements of the cleaning code.

3.1.4 Example (Initial Selection)

In order to run through the first three steps of the protocol let's consider the DMWR example from section 2.4.1:

2.3.1 Remove part from aircraft landing gear.
2.3.2 Clean part with a rag soaked with MEK.
2.3.3 Examine part for cracks using liquid dye penetrant process.

If further research determines that the part is aluminum, then it is known that:

- The part being cleaned is to be inspected using liquid dye penetrant inspection.
- Since the part is being removed from an in-service aircraft, it has been subjected to at least light maintenance soils, but more likely heavy maintenance soils because it is being removed from the landing gear.
- By researching part drawings it is determined the part is made of aluminum.

Using Table A-3 to ascertain the Cleaning Code, the determination is made that the proper Cleaning Code is 5-C. This means:

- Level of Cleanliness is 5 (measured against soil class IV).
- Material Compatibility Test Protocol is C, which requires a
    - Total Immersion Corrosion Test
    - Effects on Unpainted Surfaces Test, and a
    - Sandwich Corrosion Test

Then, any product which has been successfully evaluated against the 5-C test requirement is an acceptable cleaner for the stated maintenance action.

3.2 Down Selecting - Consideration of Other Factors

Following the three step approach to arrive at a group of cleaning products which are technically acceptable from the standpoint of cleanliness and material compatibility, is the most important aspect of the cleaning agent selection effort. The work of the engineer is not however complete. There are additional factors which must be considered before narrowing the choice of products down to one or two. The final two steps will consider the following additional factors: the consideration of other physical, chemical, environmental, health and safety and economic properties, and the type of equipment to be used.

3.2.1 Step 4: Consider Other Factors

- From the acceptable cleaners determined in step 3, take into account ***environmental concerns*** (see 2.4.6) and select the most environmentally acceptable cleaner (Table A-6, Appendix A).

- Consider ***physical and chemical properties*** (see 2.4.7) of the acceptable cleaners which important to the facility (see Table A-7, Appendix A for a partial list).

- Consider ***other technologies*** (see 2.4.8) to satisfy your cleaning requirement

3.2.2 Step 5: Select Equipment

- Determine the shape [Note: Other factors such as part size, throughput, footprint and part weight should also be considered when determining the appropriate cleaning equipment.] of the part based on the descriptions presented in Table A-8 (Appendix A).
- Use the shape of the part to determine the ***appropriate cleaning equipment*** (see 2.4.9) which can be used from Table A-9 (Appendix A).

3.2.3 Example (Down selecting)

Assume that five cleaning products were determined to be acceptable after completion of protocol step 3:

Product X:	Aqueous cleaner; flash point 100 °F
Product Y:	Aqueous cleaner; flash point 140 °F
Product Z:	Aqueous cleaner; flash point 140 °F
Product AA:	Semi-aqueous cleaner
Product BB:	Solvent type-I cleaner

From step 4, products AA and BB can be eliminated because they do not represent the most environmentally acceptable alternative (see Table A-6). If flash point is a critical evaluation factor for the facility, product X can then be eliminated because it has a lower flash point than the other two alternatives.

If the part is a solid part, then from step 5, any of the equipment types listed in Table A-9 can be used, and the final down select to either product Y or Z may be a function of product, process or equipment costs.

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U.S. Army Solvent Substitution Program - Appendix A - Draft

Protocol Tables

Table A-1 . Classes of Soils

Soil Category	Title	Soil Examples
I	Light Manufacturing Soils	• Machine tool coolants (water-based) • Machine tool lubricants (hydrocarbons)
II	Heavy Manufacturing Soils	• Category I soils, plus: • Extrusion Waxes • Silicon Oils • Silicon Greases • Synthetic Lubricants and preservatives • 0-80 microns particulate*
III	Light Maintenance Soils	• Category II soils plus: • 0-200 microns particulate* • Cured thickness: 0.2-0.4mm of soil
IV	Heavy Maintenance Soils	• Category III soils plus: • Heavy hydraulic oils • Water and hydrocarbon based fluorescent dye penetrants • Cured thickness: 0.4-0.8 mm of soil

* Note 6 ASTM G-121

Table A-2. Levels of Cleanliness

LEVEL	INSPECTION TYPE	DESCRIPTION
1	**Visual Inspection (White Light)**	The item is inspected for the presence of contaminants under strong white light and for the absence of accumulation of lint fibers. This method will detect particulate matter larger than 50 microns and moisture, oils, greases, etc., in visual amounts.
2	**Wipe Test (White Glove Test)**	Should be used to detect oils and other surface contaminants which may be inaccessible or undetectable by visual inspection. Rub the surface lightly with a clean white paper (specify paper), then examine under white light. The area should not be rubbed hard enough to remove the oxide film, as this could be confused with surface contamination.
3	**Water Break Test**	This test may be used to detect some oily residues not found by other means. Wet with a spray of distilled water. This should form a thin layer and remain unbroken for at least 5 seconds. "Beading" of water droplets indicates the presence of oil contaminants.
4	**ASTM-G-122 Standard Test CEF > 80%**	Test method is based on coupon testing to determine the effectiveness of cleaners and uses the weight of the contaminant removed to determine the cleaning efficiency.
5	**ASTM-G-122 Standard Test CEF > 95%**	Test method is based on coupon testing to determine the effectiveness of cleaners and uses the weight of the contaminant removed to determine the cleaning efficiency.

Table A-3. Cleaning Code Identification Matrix

REASON FOR CLEANING MATERIAL TYPE	PreClean*	Metallic Bonding* 1	NDT*	Bonding*	Pre-paint*	Cosmetic*	Hydrau Parts*
Carbon & Low Alloy Steel	1-A	3-A	5-A	4-D	3-A	2-A	3-A
Super Alloy - Cobalt	1-A	3-A	5-A	4-D	3-A	2-A	3-A

Super Alloy - Nickel	1-A	3-A	5-A	4-D	3-A	2-A	3-A
Super Alloy - Titanium	1-B	3-B	5-B	4-E	3-B	2-B	3-B
Stainless Steel	1-A	3-A	5-A	4-D	3-A	2-A	3-A
Iron	1-A	3-A	5-A	4-D	3-A	2-A	3-A
Aluminum	1-C	3-C	5-C	4-F	3-C	2-C	3-C
Magnesium	1-C	3-C	5-C	4-F	3-C	2-C	3-C
Brass	1-C	3-C	5-C	4-F	3-C	2-C	3-C
Bronze	1-C	3-C	5-C	4-F	3-C	2-C	3-C
Copper & Alloys	1-C	3-C	5-C	4-F	3-C	2-C	3-C
Metal Honeycomb	1-A	3-A	5-A	4-D	3-A	2-C	3-A
Rubber Compounds	1-G	N/A	N/A	1-H	3-G	2-G	3-G
Thermoset Plastics	1-J	3-J	N/A	4-J	3-J	2-J	3-J
Thermo Plastics	1-I	3-I	N/A	4-J	3-I	2-I	3-I
Acrylics	1-K	3-K	N/A	4-L	3-K	2-K	3-K
Polycarbonates	1-M	3-M	N/A	4-N	3-M	2-M	3-M
Optics	1-J	3-J	N/A	4-O	3-J	2-J	N/A
Wiring (Insulation)	1-P	N/A	N/A	N/A	3-P	2-P	3-P
Leather & Fabrics	1-Q	N/A	N/A	4-Q	3-Q	2-Q	N/A
Painted Surfaces	1-R	N/A	N/A	N/A	3-R	2-R	3-R
Polysulfides	1-S	N/A	N/A	4-T	3-S	2-S	3-S

Footnotes:

* The Cleaning Codes are in the following format: (Cleanliness Level (-) Test Protocol).

1) Metallic Bonding includes plating, welding, metallic spray, and any other metal-metal fusing, reduction processes or chemical treatment.

2) The recommended Cleanliness Levels are *minimums,* and may be exceed as necessary. This is especially relevant with regard to adhesive bonding of composites.

Table A-4. Specific Test Titles and Standards

TEST #	TITLE	STANDARD	STANDARD TITLE
1	Total Immersion Corrosion	ASTM D-930/ ASTM F-483	Method for Total Immersion Corrosion Test for Aircraft Maintenance Chemicals
2	Effects on Unpainted Surfaces	ASTM F-485	Test Method for Effects of Cleaners on Unpainted Aircraft Surfaces
3	Effects on Painted Surfaces	ASTM F-502	Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces
4	Hydrogen Embrittlement	ASTM F-519	Method for Mechanical Hydrogen Embrittlement Testing of Plating Processes and Aircraft Maintenance Chemicals
5	Sandwich Corrosion	ASTM F-1110/ SAE ARP 1512	Test Method for Sandwich Corrosion Test
6	Stress Corrosion of Titanium Alloys	ASTM F-945/ SAE ARP 1795A	Test for Stress Corrosion of Titanium Alloys
7	Polyamide Wire	MIL-C-85570	Test for Polyamide Wire Compatibility
8	Stress Crazing of Acrylic Plastics	ASTM F-484	Test Method for Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds
9	Rubber Compatibility	AMS 3204/3209	Test for Rubber Compatibility
10	Low-Embrittling Cadmium Plate Corrosion	ASTM F-1111	Corrosion of Low Embrittling Cadmium Plate by Aircraft Maintenance Chemical
11	Stress Crazing of Polycarbonate Plastics	ASTM F-484	Test Method for Stress Crazing of Acrylic Plastics in Contact with

			Liquid or Semi-Liquid Compounds
12	Effects on Polysulfide Sealant	ASTM D-2240	Test Method for Rubber Property - Durometer
13	Floating Roller Peel Resistance of Adhesives	ASTM D-3167-76	Floating Roller Peel Resistance of Adhesives
14	Peel Resistance of Adhesives	ASTM D-1876-72	Peel Resistance of Adhesives
15	Climbing Drum Peel Test for Adhesives	ASTM D-1781-76	Climbing Drum Peel Test for Adhesives
16	Strength Properties of Adhesives in Shear by Tension Loading	ASTM D-1002-72	Strength Properties of Adhesives in Shear by Tension Loading
17	Determining Durability of Adhesives Joints Stressed in Shear	ASTM D-3762-79	Adhesive Bonded Surface Durability of Aluminum (Wedge Test)
18	Adhesive-Bonded Surface Durability of Aluminum (Wedge Test)	ASTM D-3762-79	Adhesive Bonded Surface Durability of Aluminum (Wedge Test)
19	Peel or Stripping Strength of Adhesive Bonds	ASTM D-903-49	Peel or Stripping Strength of Adhesive Bonds

Table A-5. Test Protocol Requirements

PROTOCOL	APPLICABLE TESTS (from Table A-4)
A	1, 2, 4, 5, 10
B	1, 2, 4, 5, 6, 10
C	1, 2, 5
D	1, 2, 4, 5, 10,13, 14, 15, 16, 17, 18, 19
E	1, 2, 4, 5, 6, 10, 13, 14, 15, 16, 17, 18, 19
F	1, 2, 5, 13, 14, 15, 16, 17, 18, 19
G	2, 9, 12
H	2, 9, 13, 14, 17, 19
I	8, 11, 12
J	8, 11, 12, 13, 14, 15,16, 17, 18, 19
K	8
L	8, 13, 14, 15, 16, 17, 18, 19
M	11
N	11,13, 14, 15, 16, 17, 18, 19
O	13, 14, 15, 16, 17, 18, 19
P	2, 7, 9, 12
Q	2
R	1, 3
S	12
T	12, 13, 14, 15, 16, 17, 18, 19

Table A-6 Environmental Preferability

Preference	Cleaner Chemistry	Product Examples
1	Aqueous	Detergents, Soaps (non-terpene)
2	Semi-Aqueous	Emulsion Cleaners (Soluble oils, water reducible terpenes) Others (Ammonia Solution, 10% Isopropanol)
3	Solvents - Type 1 (Low vapor pressure HC (<7mm Hg), not listed as HAPs or SARA 313)	Paraffinic and Aliphatic Hydrocarbons (Stoddard Solvent, Varsol, Naptha) Exempt Halogenated Solvents
4	Other Solvents (Non-ODC)	MEK, Acetone Other Halogenated Solvents

Table A-7. Basic Tests for Non-critical Properties

TEST	TITLE	STANDARD	APPLICABLE SECTION
A	Flash Point	ASTM D-56/ASTM D-92	N/A
B	pH Value	ASTM E-70	N/A
C	Foaming Properties	MIL-C-87937	Sect. 3.12
D	Toxicity	MIL-C-87937	Sect. 3.3
E	Biodegradability	MIL-C-87937	Sect. 3.3.4
F	Volatility	MIL-C-87937	Sect. 3.5.2
G	Residue Rinsibility	MIL-C-87937	Sect. 3.5.3
H	Temperature Stability	MIL-C-87937	Sect 3.6.1 and 3.6.2

Table A-8. Shape of Component Being Cleaned

SHAPE	DESCRIPTION
X	Solid part or parts with large or shallow holes
Y	Hollow parts, or parts with small or deep holes
Z	Delicate and honeycomb composite parts

Table A-9. Equipment Selection Table

		APPLICATION			
EQUIPMENT NUMBER	**PROCESS TYPE**	**General Pre - Clean**	**Part Class "X"**	**Part Class "Y"**	**Part Class "Z"**
1	Agitated Bath-Cold	No	Yes	Yes	No
2	Agitated Bath-Hot	No	Yes	Yes	No
3	HP Spray-Glove box	No	Yes	No	No
4	HP Spray-Rotating Spray	No	Yes	No	No
5	HP Spray-Turntable	No	Yes	No	No
6	Hand Wipe	No	Yes	Yes	Yes
7	Immersion Bath-Cold	Yes	Yes	Yes	No
8	Immersion Bath-Hot	Yes	Yes	Yes	No
9	Manual-Steam Clean	Yes	Yes	Yes	No
10	Manual - Mechanical	Yes	Yes	Yes	No
11	Spray Booth	No	Yes	No	No
12	Spray Bottle	No	Yes	Yes	Yes
13	Ultra Sonic Immersion	Yes	Yes	Yes	Yes
14	Vapor Degreaser	No	Yes	Yes	Yes

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4 AUTHORS (Last name, first name, middle initial If military, show rank, e g Doe, Maj John E)

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The stripping effectiveness of Fine Organics FO606 and Turco 5668 have been evaluated and compared to Oakite Stripper SA Testing was carried out in the Chemical Cleaning Facility, FMF Cape Scott on pipe sections and elbows coated with a white powder epoxy coating as well as pipe brackets and valve covers coated with a black spray epoxy coating. All paint strippers were used in accordance with the manufacturers recommended procedures.

The results indicate that Fine Organics FO606 removed 100% of the white powder epoxy coating after 4 hours and 90% of the black spray epoxy coating after 6 hours This result was similar to the methylene chloride based stripper that removed 100% of the white powder epoxy after 2 hours and 100 % of the black spray epoxy after 6 hours However, Turco 5668 removed 95% of the white powder epoxy after 6 hours but less than 5% of the black spray epoxy after 24 hours

Monitoring of Volatile Organic Compounds (VOCs) indicated that there were no serious health concerns with the use of N-methylpyrrolidone (NMP)/ethanolamine based solvents in properly ventilated cleaning facilities

A cost analysis indicated that Fine Organics FO606 was almost twice as expensive as Oakite Stripper SA (~$12 50 CND/L versus ~$7 00 CND/L) The cost of Turco 5668, which was ineffective as a stripper for the black spray epoxy coating, was $13 30 CND/L

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Methylene Chloride
N-methylpyrrolidone
Paint Strippers

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